

STUDIES IN A FILIPENDULA
ULMARIA L. MEADOW
ECOSYSTEM AND THE
EFFECTS OF CADMIUM



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Title and subtitle Studies in a <u>Filipendula ulmaria</u> L. meadow ecosystem and the effects of cadmium			
Abstract		A4	A5
The effects of <u>cadmium</u> on <u>biomass</u>, <u>net primary production</u> and <u>litter disappearance</u> above and below ground were studied in a tall herb meadow ecosystem with dominant <u>Filipendula ulmaria</u> L. in S Sweden. A more detailed study of the functions in an untreated ecosystem is given, including <u>Cd concentration</u> and <u>distribution</u> in plant biomass. Cadmium was added at two concentration levels to the soil in 1973. Samplings were made in 1974. <u>Filipendula</u> accounted for at least 80% of the total plant biomass. In untreated plots, maximum aboveground biomass of <u>Filipendula</u> (430 g/m²) was obtained in early August. The main part of the total biomass, 60% or more, was below ground. About half of the belowground biomass of <u>Filipendula</u> was in rhizomes. A separation into current and previous year's roots revealed the yearly turnover of roots to be 75%. Primary production was estimated by four methods of calculation, which are compared and discussed. Depending on the method used, aboveground production was estimated to 409-544 g/m² and that below ground to 386-654 g/m². From measurements of the previous year's litter, 60% might disappear within a year, while disappearance of root litter seemed to be very rapid after root death. Movement of Cd in the soil appeared to be slow. Most of the Cd in the system was retained in the soil and less than 10% was found in the biomass. Root Cd concentrations were several times that in soil. The uptake in relation to soil content and Cd distribution in plant biomass differed between untreated and Cd treated plots. The Cd concentration in plant organs decreased gradually towards the top. In the lowest Cd treatment, aboveground biomass was only slightly affected, while visual symptoms of Cd toxicity and reduced growth arose early in the season at the higher Cd treatment. Belowground organs was much more affected than aboveground ones. Especially the root biomass in the uppermost soil section (0-5 cm) was seriously decreased but in relation to untreated plots, growth was more vigorous deeper in the soil. Litter disappearance was retarded in Cd treated plots and root litter accumulated during the season.			
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STUDIES IN A FILIPENDULA ULMARIA L. MEADOW ECOSYSTEM
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The dissertation is based on the following two papers:

- Studies in a Filipendula ulmaria L. meadow ecosystem and the effects of cadmium. I. Plant biomass, primary production and litter disappearance.
- Studies in a Filipendula ulmaria L. meadow ecosystem and the effects of cadmium. II. Concentration and distribution of cadmium in plant biomass and soil.

Reference to these papers is made by their Roman numerals.

INTRODUCTION

During the 1970's the heavy metal, cadmium, and its effects on organisms has attracted much attention. It is well established that even at low levels this metal is very harmful to both man and animals. Toxicity and inhibition of growth in plants are fairly well documented. The most common objects of earlier plant studies have been agricultural and vegetable species, grown in pot soil cultures or in nutrient solutions with addition of cadmium. The tolerance of plants to cadmium varies to a considerable extent, not only between plant species but also between organs within a species. Cadmium toxicity and uptake by plants appear also to be influenced by the growth conditions, where physiochemical characteristics of the growth medium are of great importance. Information concerning effects on wild plant species is meagre, however, and for species growing under natural conditions it is critically lacking. Because of the increasing rate of cadmium dispersal to the environment, such information would be of great interest.

In this work, the effects of cadmium in a tall herb meadow with dominant Filipendula ulmaria L. (in the following text named Filipendula only) was studied. The study area is situated ca 18 km S of Kristianstad, S Sweden. Other more abundant herbs of the area are Vicia cracca L., Galium aparine L., Galeopsis tetrahit L. and Urtica dioica L. The soil, a peaty mull, is primarily characterized by a high cation exchange capacity, high organic matter and calcium content and a surface pH about neutral. The almost level area has a high ground water table for most of the year. The simple structure of the ecosystem with only one dominating species and a yearly renewal of aboveground biomass proved to be a great practical advantage. However, to understand the ecological role of cadmium and as previous works on such an ecosystem are almost lacking, it was necessary to make a more detailed study of the functions also in an untreated ecosystem. Under conditions with and without soil-applied cadmium at different cadmium levels, the aims of this work were to study:

- seasonal development and vigour of the plant (Filipendula)
- seasonal changes and distribution of above- and belowground biomass
- above- and belowground annual net primary production
- formation and disappearance of litter
- uptake by and distribution of cadmium in the plant (Filipendula) in relation to cadmium content of the soil
- seasonal changes in distribution of cadmium in above- and belowground biomass.

ABOVE- AND BELOWGROUND BIOMASS AND NET PRIMARY PRODUCTION IN AN UNTREATED ECOSYSTEM (I).

Under undisturbed conditions, the dominant Filipendula seems to have a high capacity to outcompete most other species. Besides the fairly thick layer of litter, the dense root and rhizome layer together with the rapidly developing leaf can-

opy from April onwards probably allows other species few opportunities to germinate and grow.

Maximum aboveground biomass of Filipendula (430 g/m^2) was obtained in early August, being 73% of the aboveground biomass of all species. The biomasses of the other species mentioned earlier made up 2-8%. The flowering period of Filipendula was of long duration and in August only about 20% of the shoots were fertile. As in most other perennial species, the reproductive sexual organs proportionally made up a very small share of the total aboveground biomass (2%, the inflorescences included).

The below- to aboveground biomass ratio was also characteristic of a perennial species, i.e. the largest proportion (at least 60%) of total biomass was below ground. Throughout the main part of the growing season more than half of the belowground biomass of Filipendula was in rhizomes. The roots of Filipendula were separated in old roots, mainly formed during the year before, and new roots formed during the current season. Separation of roots was also made at various soil depths. In the manner typical of several perennial species, the horizontal dispersion of the root system exceeded the vertical one, giving a relatively high concentration of roots in the top 5 cm of the soil. From a maximum in April the biomass of old roots decreased almost exponentially. The formation of new roots, initiated some time between April and June, increased linearly with time. Reaching a somewhat lower total biomass than that of old roots in April, the maximum biomass of new roots was measured in November. The highest turnover of roots was obtained in the uppermost soil section and as an average of all studied sections about 75% of the total root biomass might be replaced within a year. Attributed to the procedure of separating old and new roots, this turnover value is higher than has been reported in most other root studies.

The annual net primary above- and belowground production was calculated in four ways. Depending on the method used, the estimated aboveground production of Filipendula varied between 409 and 544 g/m² and that below ground between 386 and 684 g/m². Production of all species could only be estimated in two ways, resulting for above- and belowground organs in productions of 562-684 g/m² and 511-609 g/m², respectively.

ACCUMULATION AND DISAPPEARANCE OF LITTER IN AN UNTREATED ECOSYSTEM (I)

During early summer when stem leaves of Filipendula were rapidly developing, a great part of the leaves attached to the lower part of the stem died, probably due to shortage of light. The greatest litter fall, however, occurred in the late autumn. The accumulated amount of the current year's litter in November was greater than expected. About 25% of the total estimated aboveground primary production of all species had disappeared during the growing season, but only 13-16% of that of Filipendula. During the winter months the disappearance rate of litter is assumed to be very low in this area, especially due to a reduced activity of decomposers in the almost water soaked litter and soil at this time. From measurements of the previous year's aboveground litter (old litter), 60% was estimated to disappear during one year, this value being 15% lower than obtained in another similar meadow site in S Sweden. Between the areas there is a great difference, particularly in earthworm activity. In the present area, earthworms were almost lacking. The disappearance rate of root litter was significantly higher than that of aboveground litter. Of the initial amounts of roots in April an average of 70% died during the growing season. At no soil depth did the addition of dead roots cause any statistically ascertained increase of root litter mass. Although smaller fragments of root litter had to be excluded for practical reasons, the obtained result indicated that roots might decompose very rapidly after death.

UPTAKE OF CADMIUM BY FILIPENDULA (II) AND CADMIUM EFFECTS ON BIOMASS, PRIMARY PRODUCTION AND LITTER DISAPPEARANCE (I)

The addition of cadmium was made in November, 1973, by sprinkling randomized square plots within the area with cadmium solutions of two concentration levels. The amount of added cadmium was calculated to give a soil cadmium concentration of 25 $\mu\text{g/g}$ and 250 $\mu\text{g/g}$ dry weight in the top 20 cm of the soil. In the following test, the Cd treated plots are named low and high Cd, respectively, and the untreated ones, controls.

Several other studies have established that soil properties such as organic matter and calcium content, cation exchange capacity and pH are inversely related to cadmium movement in soil and plant uptake. Although the water table fluctuated and was high for most of the year, both vertical and horizontal movement of added cadmium in the soil appeared to be slow during the studied season. Thus, most of the added cadmium was retained in the surface 0-5 cm of the soil and movement down the profile and to adjacent untreated soil seemed to be very slow. Between the Cd treatments, movement was proportional to the amount of cadmium supplied. Even in the high Cd treatment, this result indicated that the adsorption maximum of the soil was not attained.

From measurements of cadmium in biomass, litter and soil components, an average of almost 90% of total amount of cadmium added in 1973 was recovered in samples from 1974. Independent of the soil cadmium concentration, less than 1% of total cadmium content in the system was taken up in aboveground plant parts. Throughout the season belowground organs of Filipendula contained 90% or more of total Filipendula biomass cadmium. In control plants cadmium concentration in roots was several times the soil cadmium concentration but the further transport to rhizomes and aboveground shoots seemed to be restricted. Probably due to root tissue damage and

occupied binding sites on the cell walls in the high Cd treated roots, the rhizome cadmium concentration was proportionately much greater than that in control rhizomes and the greatest 'barrier' for cadmium movement seemed to be between rhizomes and stems. In aboveground organs, cadmium concentrations decreased gradually towards the top at all soil cadmium levels.

At cadmium concentrations ranging from 2.0-9.8 $\mu\text{g/g}$ in aboveground organs of the low Cd treatment in August, biomass formation of the separate organs was only slightly depressed or even stimulated. Especially at the high Cd treatment, however, visible symptoms of cadmium toxicity such as chlorosis, curled leaves and stunted growth, arose early in the season. Even by June, growth was markedly retarded and reached only 67% of that of the control in August.

Belowground organs, especially the roots, were much more affected than aboveground organs. Most evident was the cadmium effect on new roots. November biomass of new roots in the uppermost soil section (0-5 cm) in low- and high Cd treatments was reduced by 36% and 80%, respectively. The depression in this section was partly compensated by a more vigorous growth in the sections below, where the cadmium concentration was significantly lower.

A determining factor in evaluating effects of cadmium on net primary production, especially that below ground, proved to be the method used when estimating the primary production. On the basis of the results obtained in this study, different methods of estimating above- and belowground production were compared and discussed. Depending on the method used, aboveground production of Filipendula was estimated to 422-558 g/m^2 at low Cd and to 278-416 g/m^2 at high Cd treatment. As estimations of rhizome production of the Cd treatments could not be made, the belowground production of low and high Cd treatments ranged from 343-348 g/m^2 and 133-150 g/m^2 , respec-

tively, being an underestimation of the true values.

In order to facilitate comparisons of litter disappearance between controls and Cd treatments, litter bags with leaf litter of Filipendula were used. It was apparent that cadmium may reduce the disappearance rate, which was decreased by 25% in the high Cd plots. The disappearance of root litter was also affected, resulting in accumulation of root litter in the Cd treatments.

CONCLUSIONS

The contribution of Filipendula aboveground biomass to that of all species was more than 70% in untreated ecosystem. As typical for perennial species reproductive organs made up a very small share of the biomass and at maximum in early August only about 20% of the shoots were fertile. Sixty % or more of total Filipendula biomass was below ground. Results indicated that about 75% of the root biomass might be renewed yearly and disappearance seemed to be very rapid after root death.

At Cd levels corresponding to those of locally polluted areas, cadmium appeared to be effectively bound to soil components and movement in the soil was slow. Less than 10% of total cadmium in the soil-plant system was found in plant biomass. Root Cd concentration exceeded several times that in soil but the transport of cadmium to aboveground parts seemed to be limited and there was a gradual concentration decrease towards the top of the plant. Especially at the high Cd treatment, visible symptoms of Cd toxicity arose early in the season and growth, particularly that below ground, was heavily affected. Litter disappearance rate was reduced and there was a marked accumulation of root litter during the season.

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